Herring Stock Estimates from Diving Surveys of Spawn and Related Studies in Lambert Channel in 1983

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HERRING STOCK ESTIMATES FROM DIVING SURVEYS OF SPAWN AND RELATED STUDIES IN LAMBERT CHANNEL IN 1983

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by

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ABSTRACT

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Diving surveys of herring spawn were made in Lambert Channel between March 1 and 21, 1983. Spawn samples collected on transects and survey data on spawn length and width were used to estimate egg numbers. The number of eggs estimated corresponds to 4331 t of spawners in Lambert Channel in 1983. Spawn was deposited along 10.8 km of shoreline on Denman Island and 7.4 km on Hornby Island with spawn heaviest near the centre of the spawns and near the middle of the depth range. A further 79 t were estimated to have died and sunk to the bottom over the 4.8 km^2 area fished by gillnets. Estimates of egg loss to bird predation did not exceed 5% of total spawn.

Key words: Pacific herring, spawn, diving survey, stock assessment, predation, dropout

RESUME

Haegele, C. W. and J. F. Schweigert. 1985. Herring stock estimates from diving surveys of spawn and related studies in Lambert Channel in 1983. Can. MS Rep. Fish. Aquat. Sci. 1850: 37 p.

Des plongées ont été effectuées dans le chenal Lambert entre le 1er et le 21 mars 1983 pour faire des relevés sur les oeufs de hareng. Des échantillons d'oeufs prélevés sur les transects et les données des relevés sur la longueur et la largeur des oeufs ont servi à évaluer le nombre d'oeufs. Le nombre estimé correspond à 4 331 t de reproducteurs dans le chenal Lambert en 1983. Les oeufs ont été déposés sur 10,8 km du rivage de l'Île Denman et sur 7,4 km de l'Île Hornby; ils étaient surtout concentrés au centre des frayères et près de la moitié de la gamme des profondeurs. On a évalué à 79 t les oeufs qui sont morts, puis ont coulé au fond sur les 4,8 km^2 exploités aux filet maillants. Les estimations des oeufs perdus à cause de la prédation des oiseaux ne dépassaient pas 5% du nombre total d'oeufs.

Mots-clés: hareng du Pacifique, oeufs, plongée de relevé, evaluation des stocks, prédation, perte

INTRODUCTION

Lambert Channel, between Denman and Hornby islands in the Strait of Georgia (Fig. 1), is one of the major herring spawning areas in British Columbia. This channel has also been the source of the bulk of the roe herring catch in the Strait of Georgia in recent years. Diving surveys were conducted in Lambert Channel in 1983 to determine the optimal sampling design for herring spawn surveys by divers (Schweigert et al. 1985). During these surveys a 2 km portion of coastline was sampled intensively. As well, the remainder of the spawn in Lambert Channel was surveyed at a lower intensity to obtain an estimate of total escapement. An estimate of gillnet "dropout" was also made for comparison with 1981 results (Hay et al. 1982). In this report we make estimates of escapement and dropout in Lambert Channel. As well, the distribution of eggs is determined and our survey results are compared to those obtained by Fishery Officers in their annual routine monitoring of herring spawns.

METHODS

Herring spawns were surveyed independently by Fishery Officers and SCUBA divers. Fishery Officers collected survey data from the surface from a boat by grappling for spawn and by walking the beach at low tide. From these observations, the length and width of spawns, the average layers of eggs, and bare areas were estimated (Chalmers 1983).

The spawn survey by divers was a two-stage sampling design. Transects perpendicular to the beach were the primary sampling unit and 0.50 m^2 quadrats sampled along the transect line were the secondary sampling unit. For each quadrat divers made observations on the percent cover of the vegetation, dominant vegetation type, average layers of eggs and depth. Depth was later corrected to chart datum from water levels observed at Point Atkinson (Tides and Currents, Institute of Ocean Sciences, Sidney, B.C.). At all quadrats, except on transects 45 to 58 (Longbeak Point), samples were collected. Samples consisted of all the rooted or attached vegetation, and the eggs adhering to it, within the quadrat. These samples were separated by vegetation classes (Haegele et al. 1979) into fractions, which were then weighed. Except for quadrats on transects 33 to 44 (Komas Bluff) a weighed subsample of fractions was preserved in a 1 L jar for subsequent egg enumeration. For quadrats with preserved samples (Fillongley Park, Whalebone Point, Phipps Point, and Ford Cove), eggs on vegetation were estimated by counting all eggs in a weighed subfraction of the 1 L preserved sample. For samples with biomass information but no preserved sample (Komas Bluff), eggs on vegetation were estimated from a model (modified from Schweigert and Fournier 1982) incorporating layers of eggs, vegetation type, and biomass of

vegetation and attached eggs. For quadrats with only diver observations (Longbeak Point), eggs on vegetation were predicted from a model (modified from Schweigert and Fournier 1982) incorporating layers of eggs, vegetation type, and percent cover of vegetation. Eggs on the bottom substrate (rock, cobbles, etc.) were estimated from diver observations, within the quadrat, of layers of eggs and the percent of the bottom covered by eggs (Haegele et al. 1979:9) and added to eggs on vegetation.

Transects were established at every 100 m for Fillongley Park and at approximately 250 m for the remainder of the survey area. Quadrats were located at 20 m intervals along transects, except when transects were < 80 m long, in which case they were located at 10 m intervals. The mean egg density and 95% confidence intervals were calculated for each of the six spawn units and transect means were weighted by the transect length in determining this mean.

The inner and outer edge of spawns were determined from measurements along transects and the end of spawns beyond the outer transects were determined on exploratory dives. This information was plotted on maps of marine vegetation at a scale of 1:6000 (Haegele and Hamey 1981), the boundaries of the spawn contoured, and the area of the spawn measured using an Apple graphics tablet. Spawner biomass (tonnes) was estimated as the product of spawn area, egg density, and 10^{-8}, which assumes 200 eggs$\cdot$gm^{-1} female weight (Hay 1985) and a 1:1 sex ratio. The area of spawn by 1 m depth interval was similarly determined. Mean percent cover, mean egg layers and mean eggs$\cdot$m^{-2} were calculated for depth intervals from samples obtained within the 1 m interval.

A gillnet roe fishery was conducted along the Denman Island shore during early spawning (February 27 to March 1). To estimate "dropout" fish that were killed (Hay et al. 1982), dead fish within 1 m on one or both sides of the transect line were counted by divers in the Fillongley Park section. Dead fish were summed by 100 m distance intervals from shore and an estimate of total dropout was made, assuming 8 km of shoreline was fished and fishing occurred within 600 m of shore, an estimate made from observing the fishing fleet.

RESULTS

BIOMASS ESTIMATES

The spawner biomass for Lambert Channel was determined from results of the diving survey (Table 1). The diving survey results were compared to the Fishery Officer survey results for Lambert Channel (Table 2).

There were six spawns identified from the diving survey (Figs. 1 to 7). Along the Denman Island shore 3526 t spawned in a first wave between February 27 and March 4, 1985 and along the Hornby Island shore 805 t spawned in a second wave on March 14, 1985 (Table 1). The 95% confidence interval for the egg density estimates was within 21% (Fillongley Park) and 62% (Longbeak Point) of the mean. The 1985 roe fishery harvested 10,052 t in Lambert Channel, hence the total stock was 14,383 t.

Fishery Officers described the Lambert Channel spawn in 19 patches (Table 2). Relative to the diving survey estimates, Fishery Officer estimates of (1) length were 1.26·diver length, (2) width were 0.54·diver width, (3) area, which was corrected for bare patches, were 0.47·diver area, and (4) egg layers were 3.73·diver layers.

SPAWN DISTRIBUTION

Spawn was deposited along 10.75 km of shoreline on Denman Island and along 7.38 km of shoreline on Hornby Island and between 3 m below and 3 m above chart datum. Egg density along the two shorelines, in terms of layers of eggs, was higher near the centre of the spawns than near the ends of the spawns (Figs. 8, 9). The differences were in most cases not significant. The distribution of spawn by depth was calculated separately for Denman and Hornby islands (Table 3) because spawn density in the +1 to +2 m depth interval was significantly higher on Denman Island than on Hornby Island (Table 4). Negligible amounts of spawn were deposited outside -2 to +2 m and 75% of the spawn was deposited below +1 m (Fig. 10). Percent cover of vegetation and layers of eggs were significantly higher in the middle of the depth range than in the upper and lower portion of the spawn and hence egg density (eggs·m^{-2}) was also significantly higher there (Table 5; Fig. 11).

The mean tide level during the incubation period (March 1 to 18 for Denman Island and March 14 to 28 for Hornby Island) was 3.4 m. The highest and lowest tide level was 5.1 and 1.1 m, respectively (Fig. 12). Hence, none of the spawn below +1 m was exposed during incubation. Spawn above +2 m was exposed a maximum of 31.3% of the incubation period for Denman Island and a maximum of 34.4% of the time for Hornby Island (Table 6). Spawn below +2 m was exposed a maximum of 4.4% of the time for Denman Island and 9.4% of the time for Hornby Island. Daylight (05:00 to 19:00 hr) exposure was generally half of total exposure (Table 6), and bird predation of eggs was observed to be limited to exposed spawn during daylight. Hours of exposure from the beginning of spawning to the time the survey was completed was less than total exposure (Table 6), hence surveys were completed before maximum predation had occurred.

DROPOUT

Dead herring were found on the bottom on each of the 18 transects that were examined for the incidence of dropout (Table 7). Extrapolating observed dead fish density over the area fished, an estimated 476,000 herring were killed but not landed in the fishery. Based on an approximate conversion of 6000 herring per tonne this was equivalent to 79 t or 0.9% of the gillnet catch. Average density of dead fish was not high at 0.1 fish$\cdot m^{-2}$.

DISCUSSION

Our egg estimates are likely to be lower than actual deposition because some eggs are removed by predators and some eggs are knocked loose from the vegetation by wave action. No major storms occurred during the incubation period and few eggs were observed washed up on the beach so loss due to wave action was probably small. However, a large number of gulls were observed to feed on exposed spawn during daylight hours. No estimate of the gull population feeding on herring spawn in Lambert Channel is available, however only spawn above +1 m was available for predation and only spawn above +2 m for any length of time. Since 95% of the spawn area was below +2 m and 73% was below +1 m and since egg density was not significantly lower between +2 and +1 m than between +1 and 0 m, it is reasonable to conclude that perhaps much of the spawn above +2 m is eaten by birds and a small amount of the spawn between +2 and +1 m is eaten by birds. Overall, this should not amount to more than 5%. Similarly, eggs from "dropout" fish may not be included in the estimate, but this also is a small amount. Assuming 5% egg loss prior to the survey and that none of the "dropout" fish spawned, then up to 4,623 t may have spawned in Lambert Channel.

Our estimate of "dropout" fish is similar to one made for the same area in 1981 (Hay et al. 1982). The 1981 estimate was for 84 t over a 4.5 km^2 area, our 1983 estimate was for 79 t over a 4.8 km^2 area. For the two years this represented 1.7% and 0.9% of the gillnet catch. This wastage does not seem unreasonably high for a fishery conducted with nets.

Egg density was higher near the centre of the spawns than at the ends which probably was the result of fish starting to spawn near the centre and spreading from there as spawning continued. Spawn was also densest at the middle of the depth range over which it was deposited. Since the percent cover of the vegetation was also highest there, this suggests that herring selected the best developed vegetation for spawning but as more fish congregated near the beach to spawn, some of them were displaced shoreward and seaward. The egg distribution observed at Lambert Channel has also been documented in spawns surveyed by divers on the north coast (Schweigert and Haegele 1984), in Barkley Sound (Haegele and Schweigert 1984) and on the west coast of Vancouver Island (Haegele and Schweigert 1985) and seems to be generally applicable to British Columbia herring spawns.

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Table 1. Survey information and estimates of egg density and spawner biomass for 1983 herring spawns in Lambert Channel.

Location	Length (km)	Area (ha)	No. of transects	No. of observations	Eggs·m^{-2}·10^{-3} (95% C.I.)	Tonnes of spawners (95% C.I.)
Longbeak Point	2.83	55.27	14	182	157[a] (60-255)	871 (332-1409)
Komas Bluff	3.00	40.55	12	104	213[b] (133-293)	864 (541-1186)
Fillongley Park	2.00	76.81	21	378	179 (142-217)	1376 (1089-1664)
Whalebone Point	2.92	36.44	11	51	114 (60-168)	415 (218-612)
All Denman Is.	10.75	209.07	58	715	-	3526
Phipps Point	4.29	47.86	16	98	132 (90-174)	631 (429-833)
Ford Cove	3.09	10.97	12[c]	50	158 (85-232)	174 (94-254)
All Hornby Is.	7.38	58.83	28	148	-	805
All Lambert Ch.	18.13	267.90	86	863	-	4331

[a]Egg density predicted from observations of layers of eggs, vegetation type and percent cover of vegetation.

[b]Egg density predicted from observation of layers of eggs and vegetation type and from biomass of eggs and vegetation.

[c]No spawn was observed on two additional transects (B3 and B5 in Fig. 7).

Table 2. Comparison of diver survey and Fishery Officer survey results for 1983 herring spawns in Lambert Channel.

Location	Transects	Diver				Fishery Officer				F.O./Diver			
		Length (m)	Av. transect length (m)	Area (ha)	Av. layers	Length (m)	Width (m)	Area[c] (ha)	Layers	Length	Width	Area	Layers
Longbeak Point	-	No spawn				686	9	0.03	1.0	-	-	-	-
	57-58	280	96	2.00	0.4	457	23	0.21	4.0	1.63	0.24	0.11	10.26
	48-56	2000	284	41.97	0.8	2377	23	1.09	4.0	1.19	0.08	0.03	4.94
	46-47	550	279	11.30	1.1	782	14	0.01	4.0	1.42	0.05	0.00	3.81
	45-58	2830	256	55.27	0.8	4302	19	1.34	3.9[a]	1.52	0.07	0.02	4.64
Kores Bluff	44	350	281	8.18	1.2	498	14	0.01	4.0	0.87	0.05	0.00	3.23
	43	300	183	4.57	2.3	No spawn				-	-	-	-
	40-42	500	200	8.33	1.4	731	114	5.02	5.0	1.46	0.57	0.60	3.60
	36-39	1100	143	13.12	1.3	1372	55	5.64	7.0	1.25	0.33	0.43	5.30
	33-35	750	102	6.35	0.6	731	46	1.67	5.0	0.97	0.46	0.25	8.33
	33-44	3000	162	40.55	1.3	3332	63	12.34	5.9[a]	1.05	0.39	0.30	4.65
Fillongley Park	1-12	1150	329	37.35	1.1	1280	64	4.10	5.0	1.11	0.19	0.11	4.57
	13-21	850	469	39.46	1.3	1315	549	35.08	4.0	1.55	1.17	0.91	3.01
	1-21	2000	389	76.81	1.2	2595	310	40.18	4.1[a]	1.30	0.80	0.52	3.39
Whalebone Point	22-25	1100	146	25.00	0.8	1702	549	46.69	4.0	1.55	3.75	1.87	4.76
	26-32	1820	66	11.44	0.7	2195	91	10.03	1.5	1.21	1.39	0.88	2.31
	-	No spawn				3475	37	8.26	5.0	-	-	-	-
	21-32	2920	95	36.44	0.7	7372	171	64.98	3.7[a]	2.52	1.80	1.78	5.00
Denman Island	1-68	10750	254	209.07	1.1	17601	135	118.84	4.1[a]	1.62	0.53	0.57	3.76

Table 2 (cont'd)

Location	Transects	Diver				Fishery Officer				F.O./Diver			
		Length (m)	Av. transect length (m)	Area (ha)	Av. layers	Length (m)	Width (m)	Area[c] (ha)	Layers	Length	Width	Area	Layers
Pripps Point	26-30	1650	151	23.40	0.8	No spawn				-	-	-	-
	23-25	740	74	5.15	2.3	1280	23	1.17	4.0	1.73	0.31	0.23	1.77
	17-22	1500	117	16.50	1.1	1554	23	1.78	6.0	1.04	0.20	0.11	5.56
	15-16	400	76	2.81	2.0	No spawn				-	-	-	-
	15-30	4290	114	47.86	1.2	2834	23	2.95	5.2[a]	0.66	0.20	0.06	4.26
Ford Cove	12-14	900	22	2.30	1.1	914	18	1.00	3.0	1.02	0.83	0.43	2.63
	10-11	600	22	1.50	1.4	366	9	0.23	4.0	0.61	0.41	0.15	2.94
	6- 9	700	64	5.50	0.9	914	23	1.35	4.0	1.31	0.35	0.25	4.44
	3- 5[b]	500	17	0.47	0.3	No spawn				-	-	-	-
	1- 2	390	25	1.20	0.7	366	23	0.21	2.0	0.94	0.88	0.18	3.03
	1-14[b]	3380	35	10.97	0.9	2560	19	2.80	3.5[a]	0.83	0.54	0.25	3.76
Hornby Island	1-30[b]	7380	81	58.83	1.1	5394	21	5.75	4.4[a]	0.73	0.26	0.10	3.93
Lambert Channel	-	18130	198	257.90	1.1	22995	108	124.59	4.1[a]	1.26	0.54	0.47	3.73

[a]Layers weighted by reported area of spawn.

[b]No spawn was observed on transects B3 and B5.

[c]Observed area corrected for patchiness.

Table 3. Area of spawn, mean egg density and number of eggs by 1 m depth intervals for herring spawn in Lambert Channel in 1983.

Location	Depth interval	Area (ha)	N	Eggs·m^{-2}·10^{-3} (95% C.I.)	No. of eggs·10^{-8} (95% C.I.)
Denman Island	-3 to -2	12.87	6	21 (0 to 42)	27 (0 to 54)
	-2 to -1	28.57	51	103 (50 to 155)	294 (143 to 443)
	-1 to 0	43.02	98	182 (129 to 234)	783 (555 to 1007)
	0 to +1	65.33	155	202 (163 to 242)	1320 (1065 to 1581)
	+1 to +2	47.45	104	187 (140 to 235)	887 (664 to 1115)
	+2 to +3	11.83	18	56 (-3 to 116)	66 (0 to 137)
Hornby Island	-3 to -2	0.59	1	5 (-)	<1
	-2 to -1	4.27	9	43 (1 to 85)	18 (0 to 36)
	-1 to 0	15.26	41	138 (64 to 212)	211 (98 to 324)
	0 to +1	25.18	65	239 (153 to 324)	602 (385 to 816)
	+1 to +2	11.41	29	100 (48 to 152)	114 (55 to 173)
	+2 to +3	2.12	3	1 (-)	<1

Table 4. Probability (Student t-test) of significant differences in percent cover, layers of eggs, and eggs·m^{-2} between Denman and Hornby islands spawn at 1 m depth intervals.

Depth interval	Parameter	Depth interval			
		-2 to -1	-1 to 0	0 to +1	+1 to +2
-2 to -1	% cover	0.43			
	Layers	0.29			
	Eggs·m^{-2}	0.07			
-1 to 0	% cover		0.86		
	Layers		0.94		
	Eggs·m^{-2}		0.34		
0 to +1	% cover			0.10	
	Layers			0.12	
	Eggs·m^{-2}			0.44	
+1 to +2	% cover				0.05
	Layers				0.00
	Eggs·m^{-2}				0.01

Table 5. Probability (Student t-test) of significant differences in percent cover of vegetation, layers of eggs and eggs·m-2 between 1 m depth intervals for Denman and Hornby islands spawn.

Location	Depth interval	Parameter	Depth interval				
			-3 to -2	-2 to -1	-1 to 0	0 to +1	+1 to +2
Denman Island	-2 to -1	% cover	0.84				
		Layers	0.68				
		Eggs·m-2	0.00				
	-1 to 0	% cover	0.05	0.02			
		Layers	0.00	0.01			
		Eggs·m-2	0.00	0.04			
	0 to +1	% cover	0.00	0.00	0.07		
		Layers	0.00	0.00	0.02		
		Eggs·m-2	0.00	0.00	0.53		
	+1 to +2	% cover	0.00	0.00	0.03	0.56	
		Layers	0.00	0.00	0.00	0.75	
		Eggs·m-2	0.00	0.02	0.87	0.63	
	+2 to +3	% cover	0.81	0.90	0.32	0.74	0.05
		Layers	0.44	0.54	0.17	0.00	0.00
		Eggs·m-2	0.24	0.23	0.00	0.00	0.00
Hornby Island	-1 to 0	% cover	-	0.51			
		Layers	-	0.07			
		Eggs·m-2	-	0.02			
	0 to +1	% cover	-	0.01	0.05		
		Layers	-	0.00	0.05		
		Eggs·m-2	-	0.00	0.08		
	+1 to +2	% cover	-	0.00	0.01	0.21	
		Layers	-	0.99	0.03	0.00	
		Eggs·m-2	-	0.08	0.40	0.01	

Table 6. Maximum hours of exposure of spawn at tide levels observed for Lambert Channel (day is from 05:00 to 19:00 hrs PST).

Location	Period	Depth interval	Exposure time (hr)			% of incubation time		
			Day	Dark	Total	Day	Dark	Total
Denman Island	March 1 - 18[a]	3 to 2	64	71	135	14.8	16.4	31.3
		2 to 1	6	13	19	1.4	3.0	4.4
Hornby Island	March 14 - 28[a]	3 to 2	69	55	124	19.2	15.3	34.4
		2 to 1	17	17	34	4.7	4.7	9.4
Longbeak Point	March 1 - 17[b]	3 to 2	57	68	125	14.0	16.7	30.6
		2 to 1	4	13	17	1.0	3.2	4.2
Komas Bluff	March 1 - 15[b]	3 to 2	47	60	107	13.1	16.7	29.7
		2 to 1	4	13	17	1.1	3.6	4.7
Fillongley Park	March 1 - 13[b]	3 to 2	43	52	95	13.8	16.7	30.4
		2 to 1	4	10	14	1.3	3.2	4.5
Whalebone Point	March 1 - 14[b]	3 to 2	44	57	101	13.1	17.0	30.1
		2 to 1	4	11	15	1.2	3.3	4.5
Phipps Point	March 14 - 21[b]	3 to 2	43	19	62	22.4	9.9	32.3
		2 to 1	11	3	14	5.7	1.6	7.3
Ford Cove	March 14 - 18[b]	3 to 2	22	21	43	18.3	17.5	35.8
		2 to 1	2	3	5	1.7	2.5	4.2

[a] From start of spawn to complete hatch.

[b] From start of spawn to completion of survey.

Table 7. Number of dead fish on bottom along transects by distance from shore and for area fished, assuming no dead fish occurred beyond 600 m from shore. (Width for transects is 1=1 m on one side of transect and 2=1 m on both sides of transect. Width for fishing area is distance along shore fished by gillnets.)

	Distance from shore (m)											
	0 to 100		100 to 200		200 to 300		300 to 400		400 to 500		500 to 600	
Location	Width	Fish	Width	Fish	Width	Fish	Width	Fish	Width	Fish	Width	Fish
Transect 3	1	0	1	9	1	1	-	-	-	-	-	-
Transect 4	2	4	2	8	2	31	2	128	-	-	-	-
Transect 5	2	5	2	15	2	27	2	21	2	0	-	-
Transect 6	1	1	1	21	1	14	1	83	-	-	-	-
Transect 7	2	0	2	29	2	90	2	13	-	-	-	-
Transect 8	1	0	1	2	1	11	1	18	1	13	-	-
Transect 9	1	1	1	31	1	26	1	36	-	-	-	-
Transect 10	-	-	-	-	1	12	1	13	1	5	1	4
Transect 11	-	-	-	-	1	2	1	11	1	3	1	0
Transect 12	-	-	1	0	1	9	1	12	1	0	-	-
Transect 13	2	0	2	5	2	10	2	7	2	2	-	-
Transect 14	-	-	2	5	2	26	2	24	2	9	2	15
Transect 15	-	-	2	20	2	31	2	27	2	43	-	-
Transect 16	2	6	2	1	2	67	2	72	2	38	2	69
Transect 17	-	-	2	0	2	50	2	65	2	35	2	80
Transect 18	-	-	2	0	2	11	2	10	2	0	2	0
Transect 19	-	-	2	0	2	1	2	0	2	0	2	0
Transect 20	-	-	2	0	2	0	2	2	2	2	2	1
Transects 3 to 20	14	17	27	146	29	419	28	547	22	150	14	169
Fishing Area	8000	9714	8000	43259	8000	115586	8000	156286	8000	54546	8000	96571

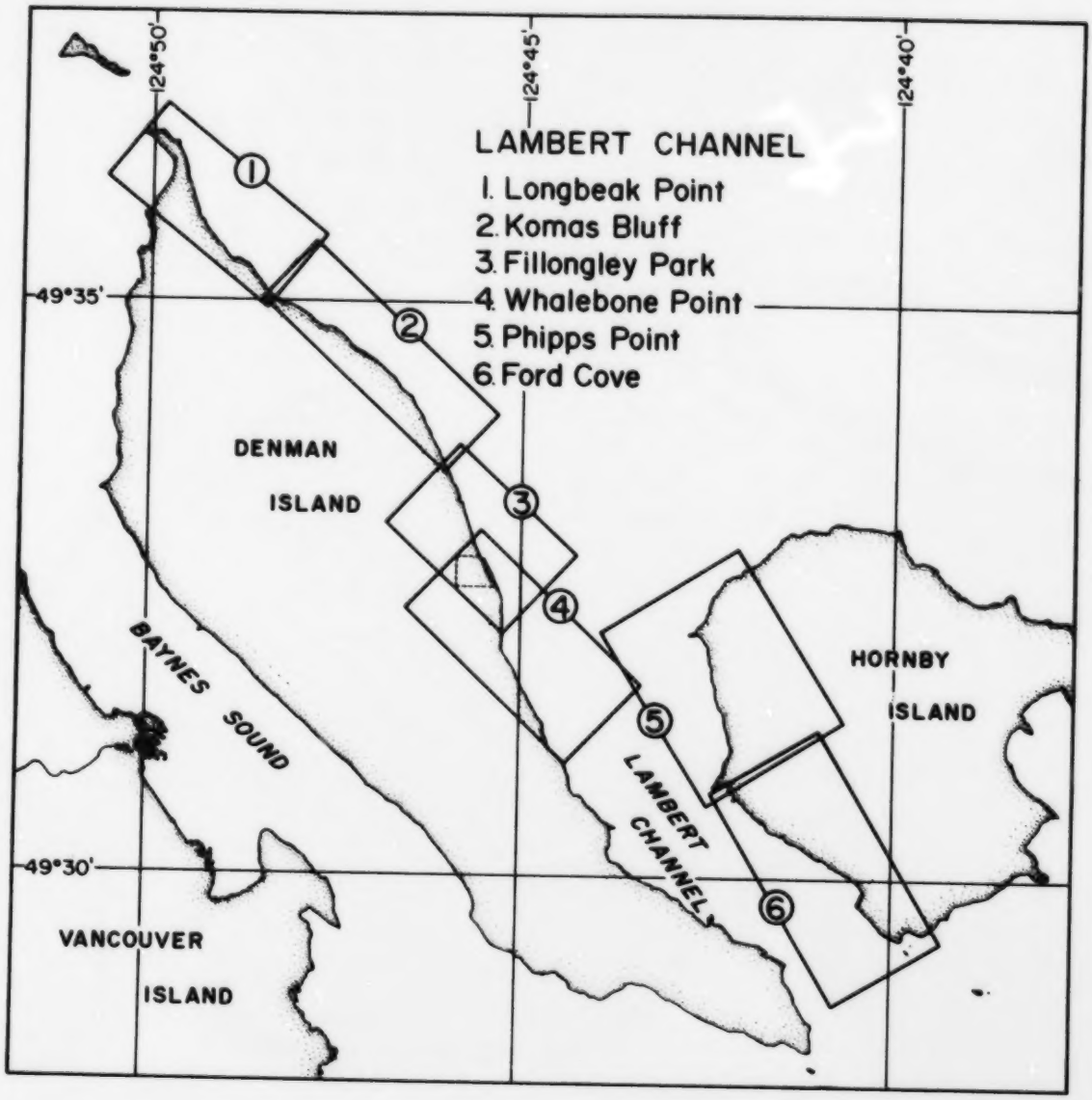


Fig. 1. Map of Lambert Channel study area. Rectangles are outlines of maps in Figs. 2 to 7.

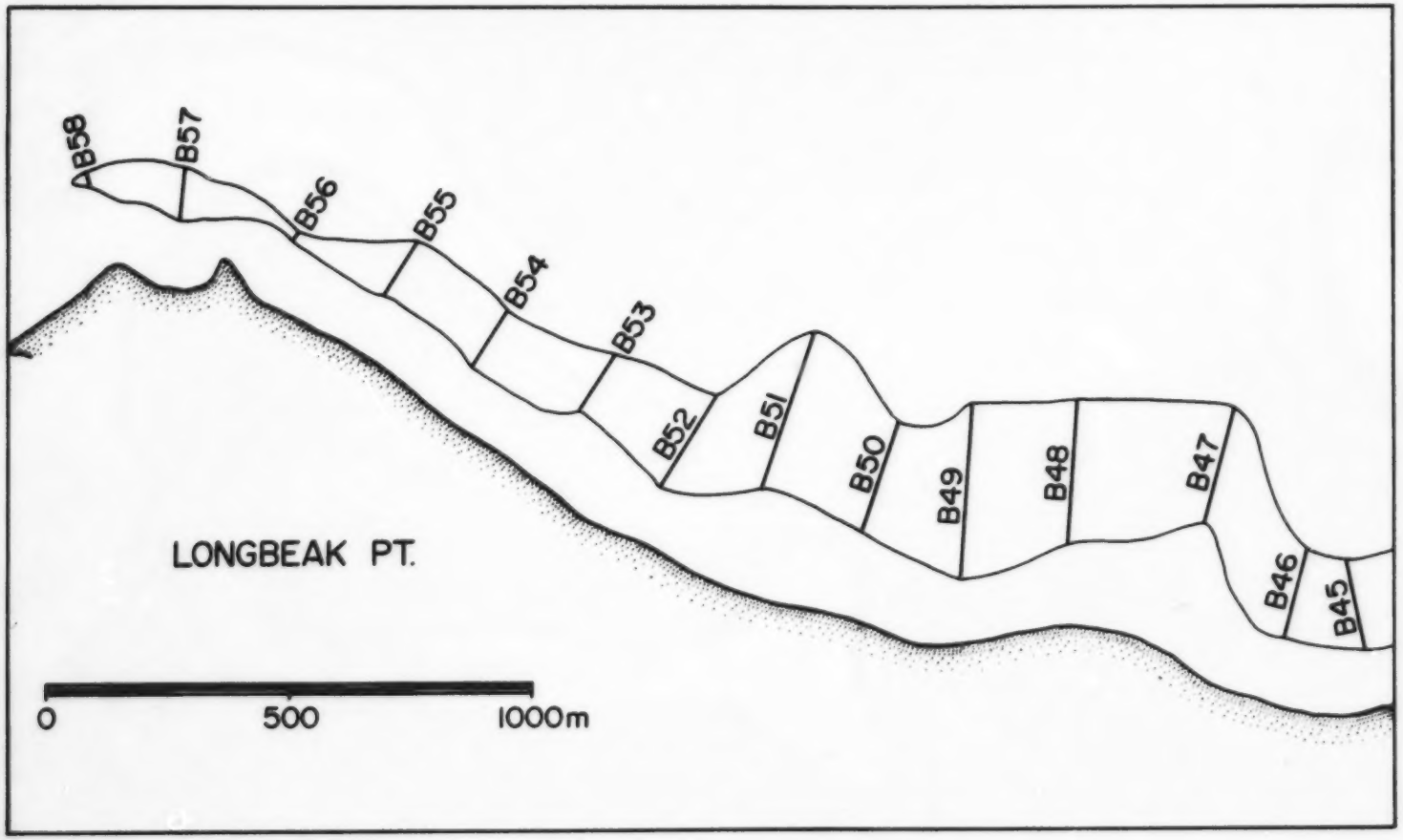


Fig. 2. Herring spawn at Longbeak Point, surveyed by divers in 1983, with transect locations shown.

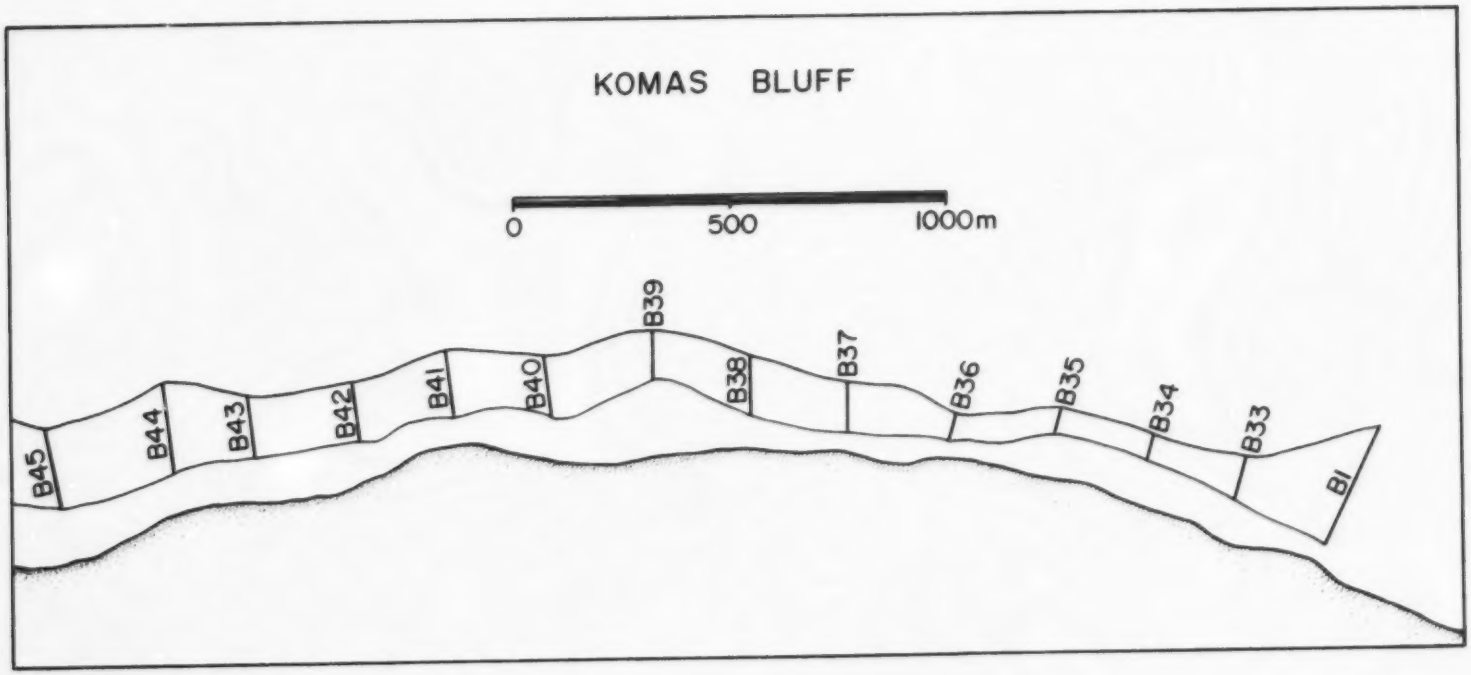


Fig. 3. Herring spawn at Komas Bluff, surveyed by divers in 1983, with transect locations shown.

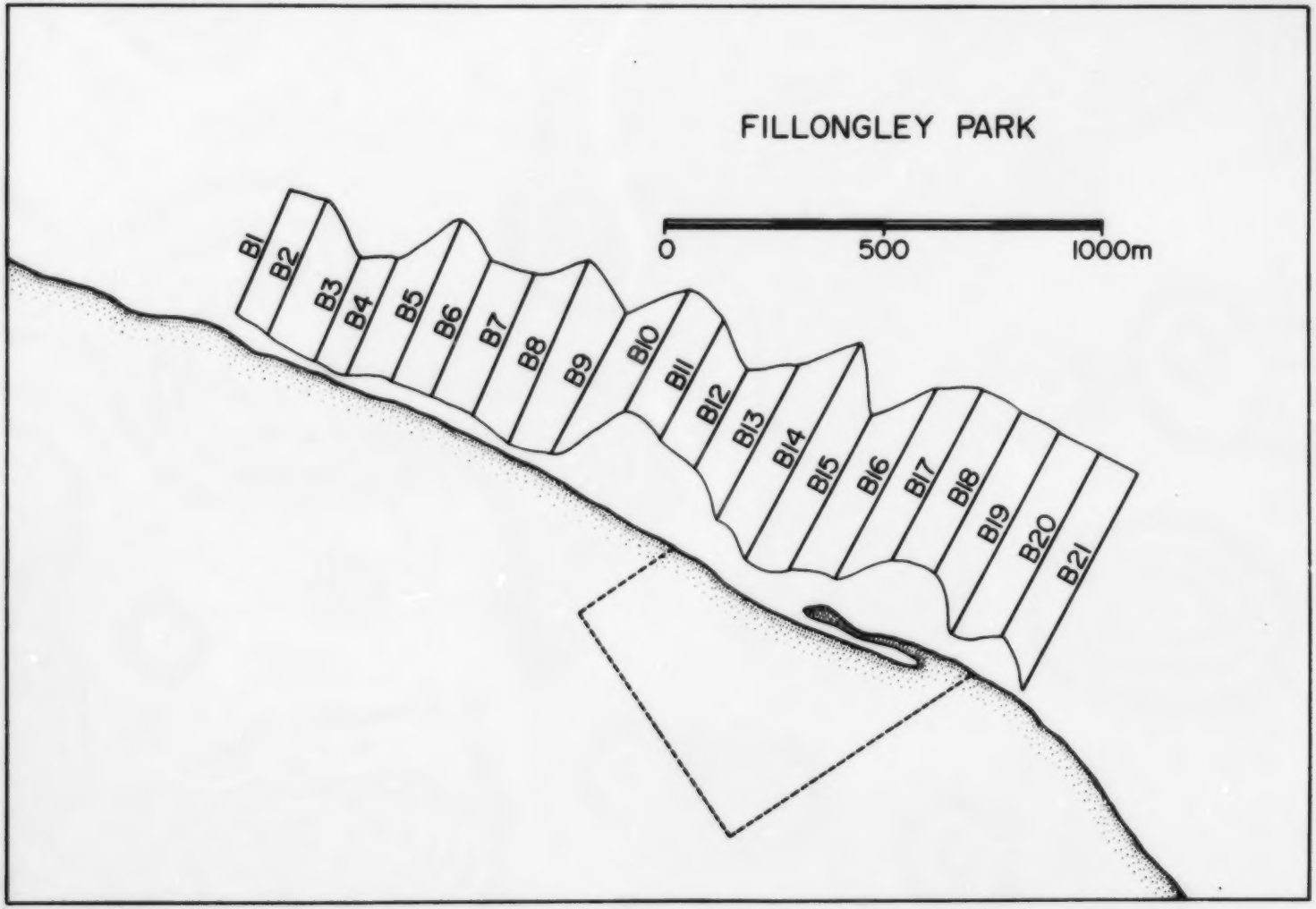


Fig. 4. Herring spawn at Fillongley Park, surveyed by divers in 1983, with transect locations shown.

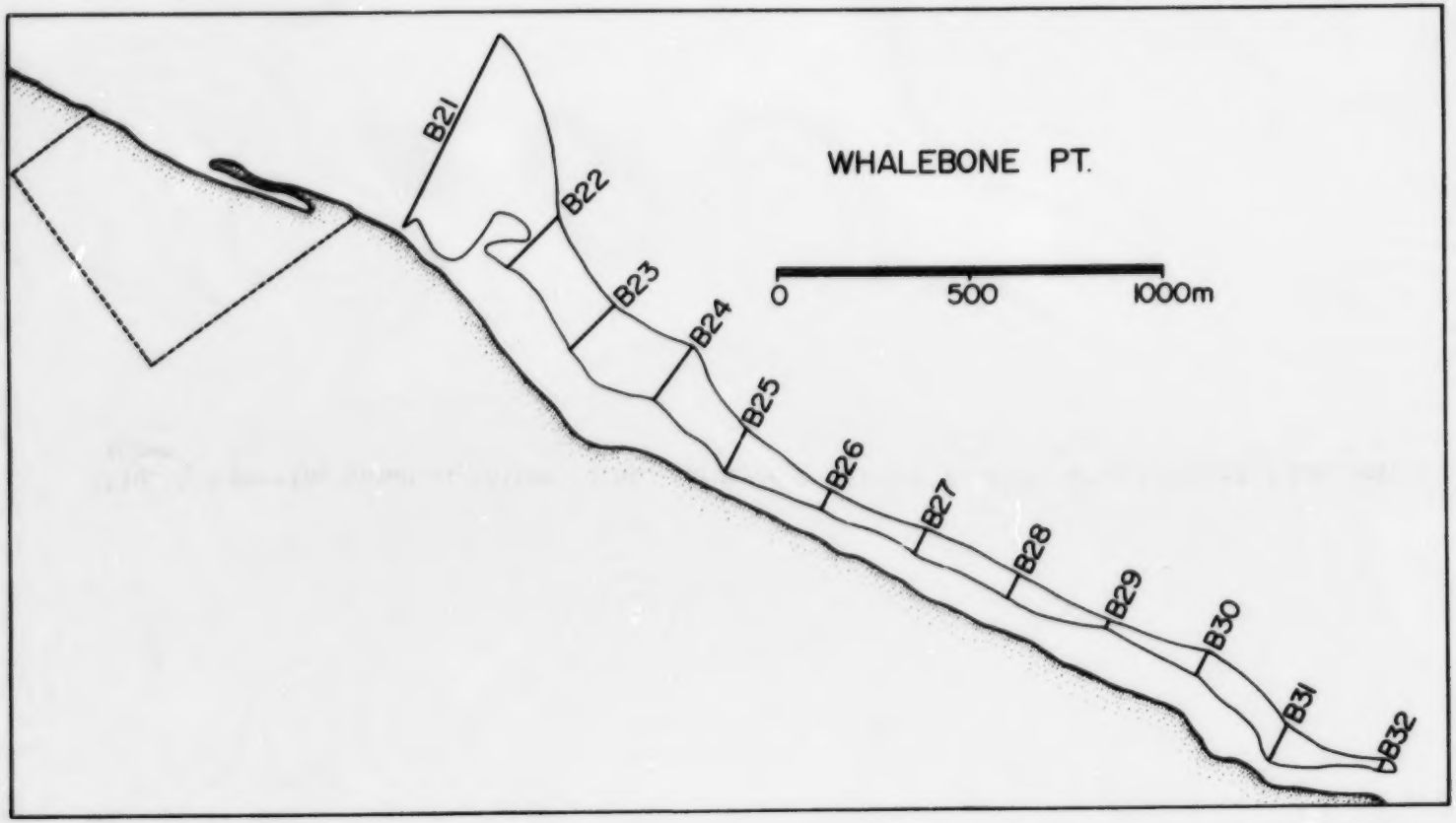
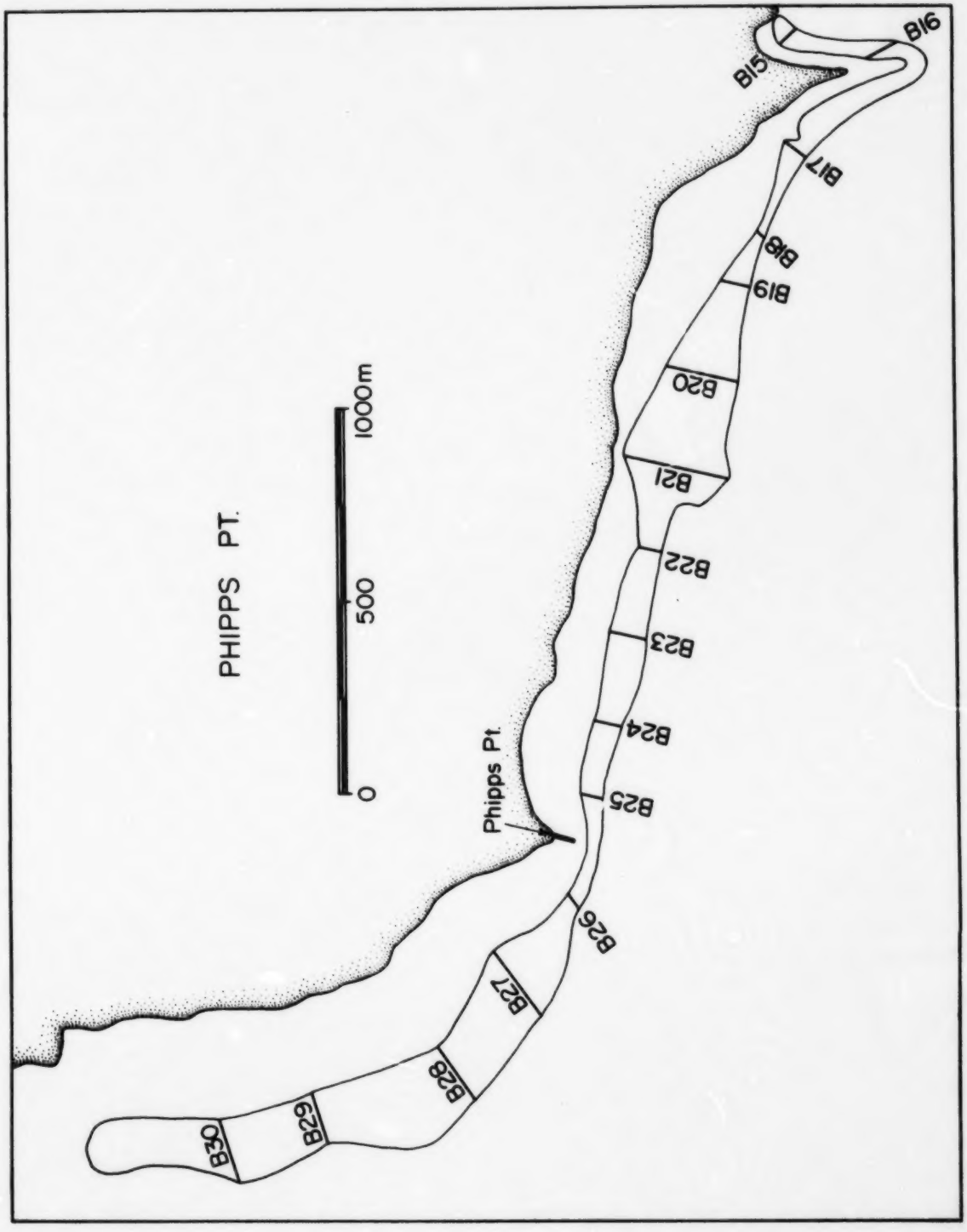


Fig. 5. Herring spawn at Whalebone Point, surveyed by divers in 1983, with transect locations shown.

Fig. 6. Herring spawn at Phipps Point, surveyed by divers in 1983, with transect locations shown.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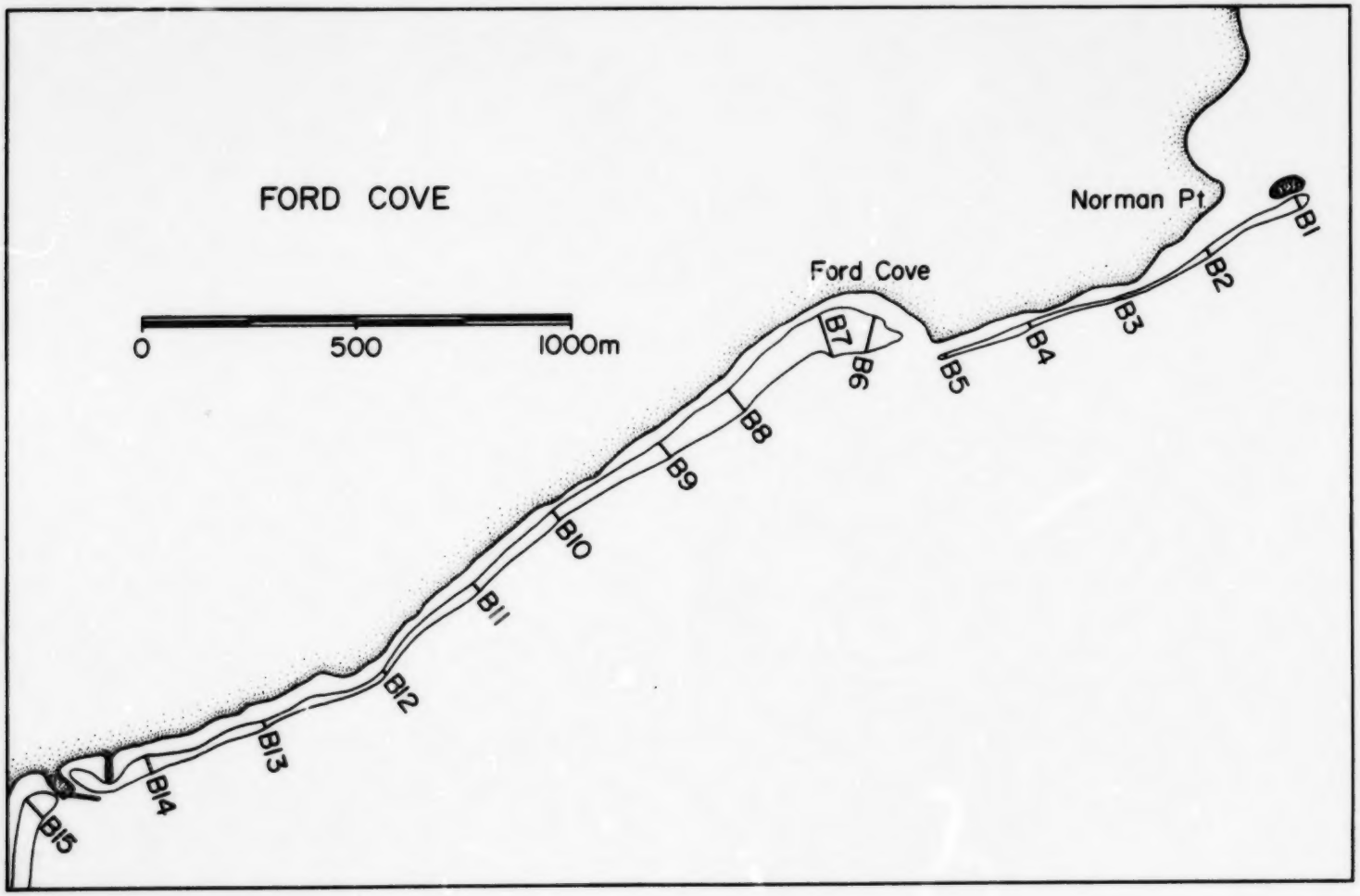

Fig. 7. Herring spawn at Ford Cove, surveyed by divers in 1983, with transect locations shown.

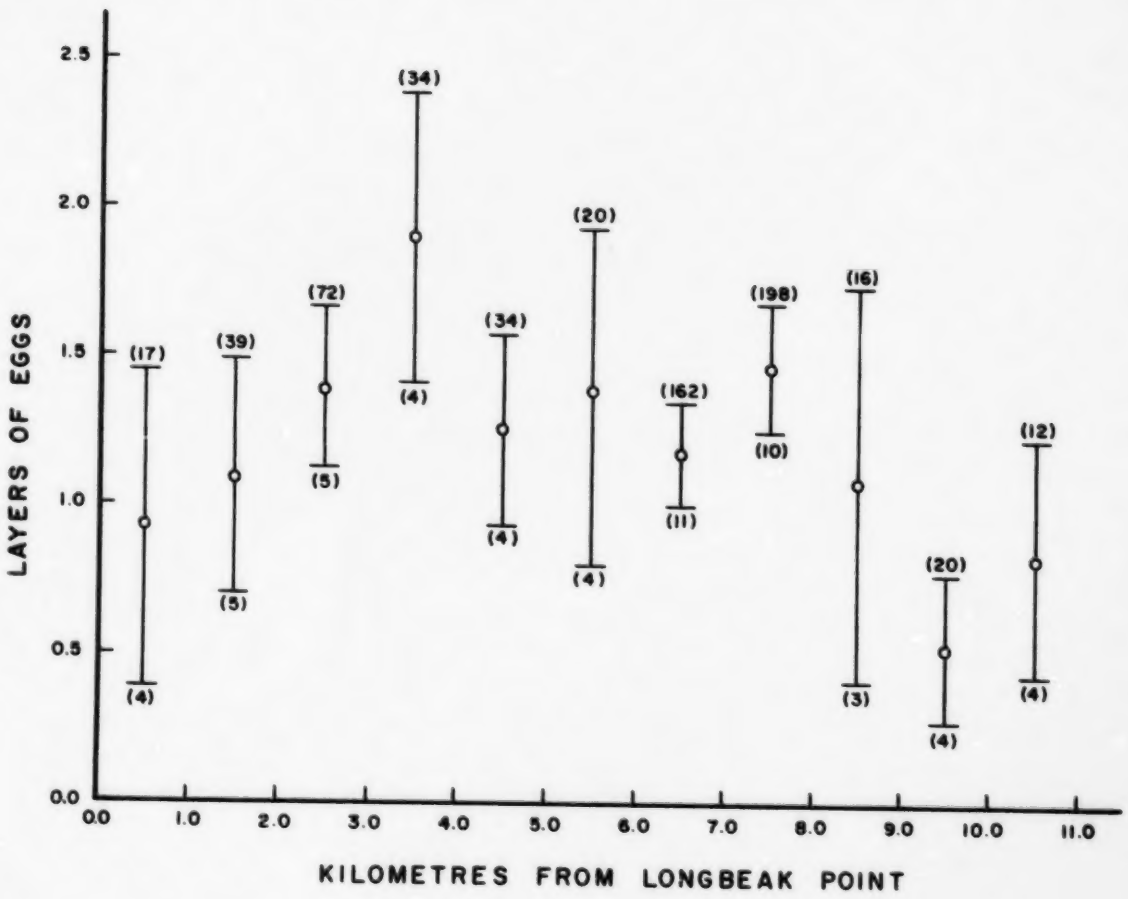

Fig. 8. Mean layers of eggs by 1 km intervals for 1983 herring spawn at Denman Island. Number of samples and number of transects are shown above and below 95% C.I.

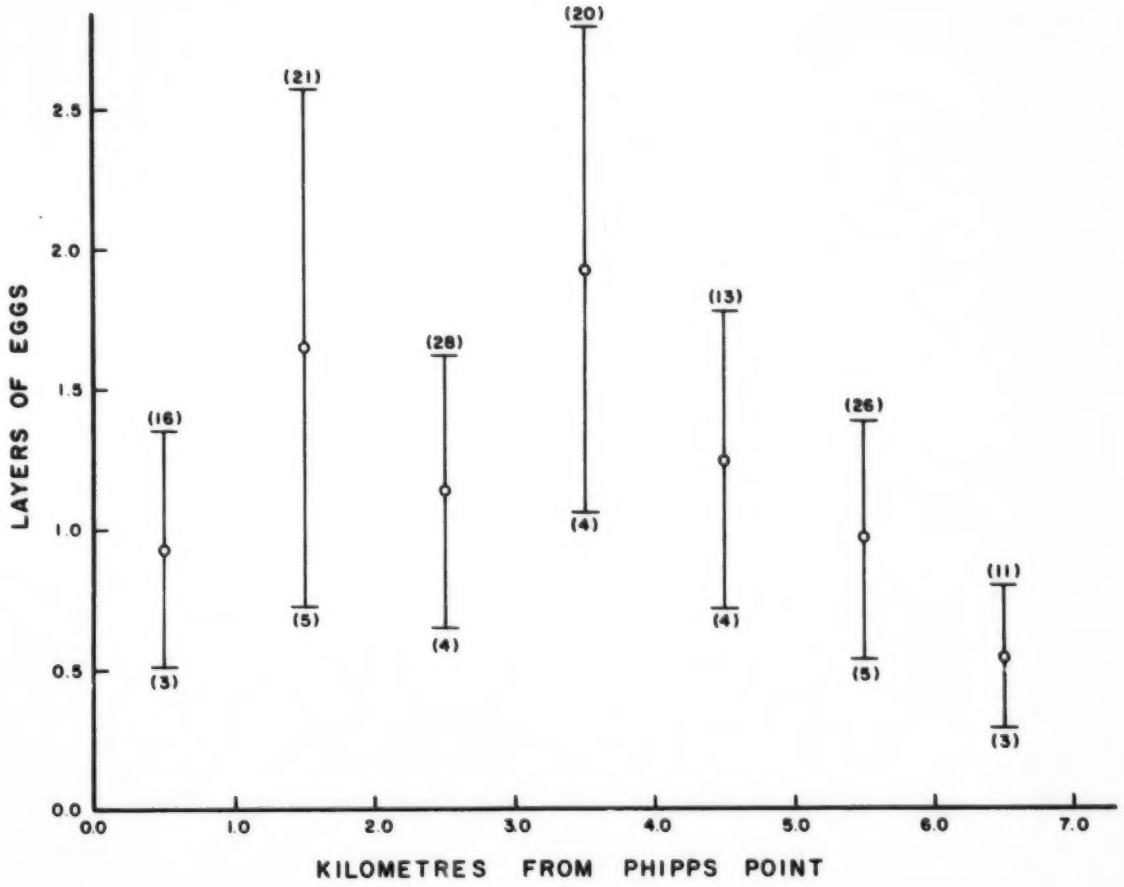

Fig. 9. Mean layers of eggs by 1 km intervals for 1983 herring spawn at Hornby Island. Number of samples and number of transects are shown above and below 95% C.I.

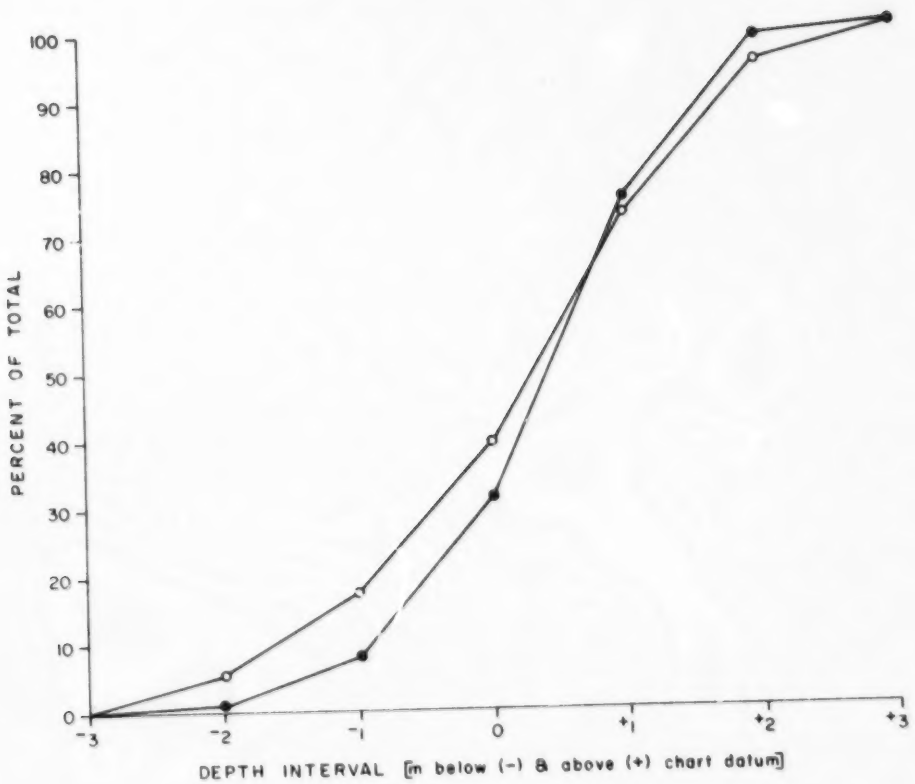

Fig. 10. Distribution of area (open circles) and number of eggs (solid circles) by depth for 1983 Lambert Channel herring spawn.

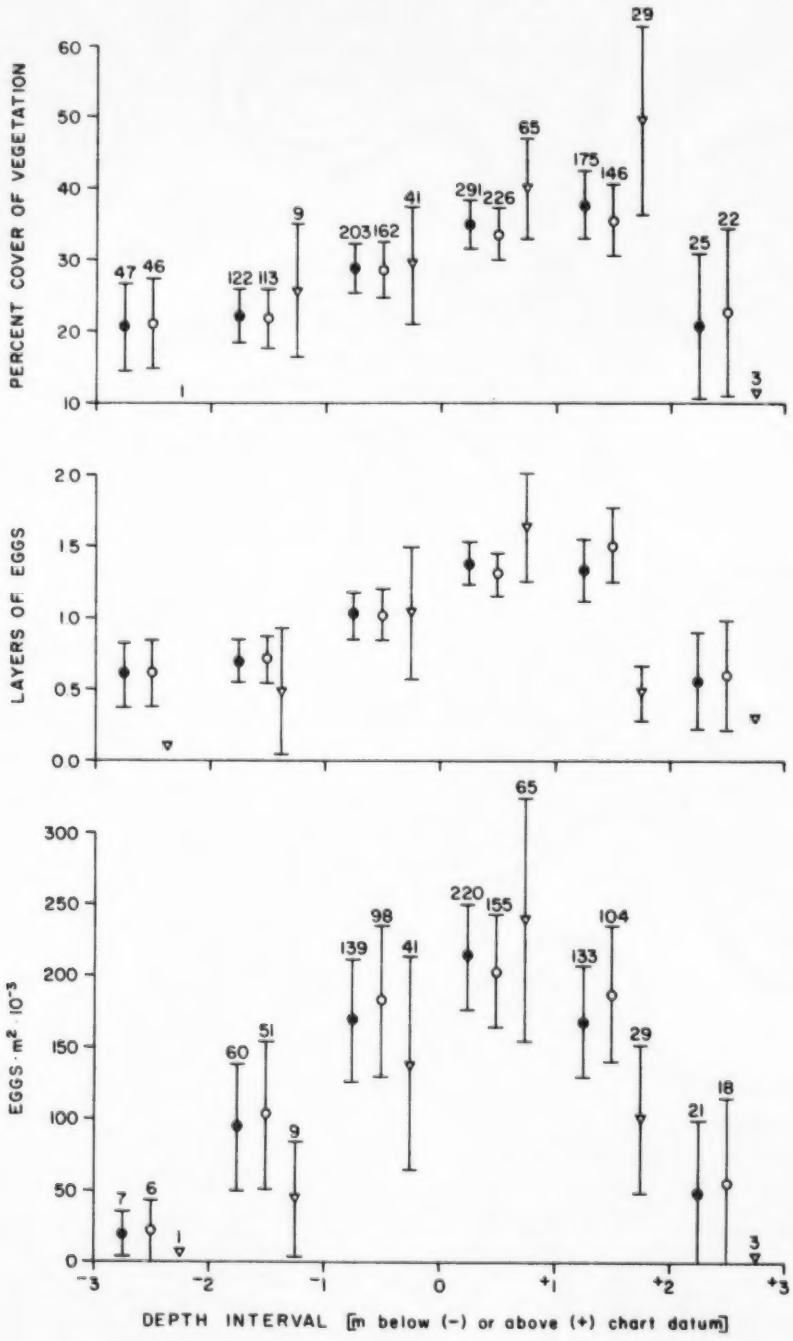

Fig. 11. Mean percent cover of vegetation, layers of eggs, and egg density, with 95% C.I. and sample numbers shown, for 1983 herring spawn at Denman Island (open circles), Hornby Island (triangles) and all of Lambert Channel (solid circles). (Sample numbers for percent cover and layers of eggs are identical.)

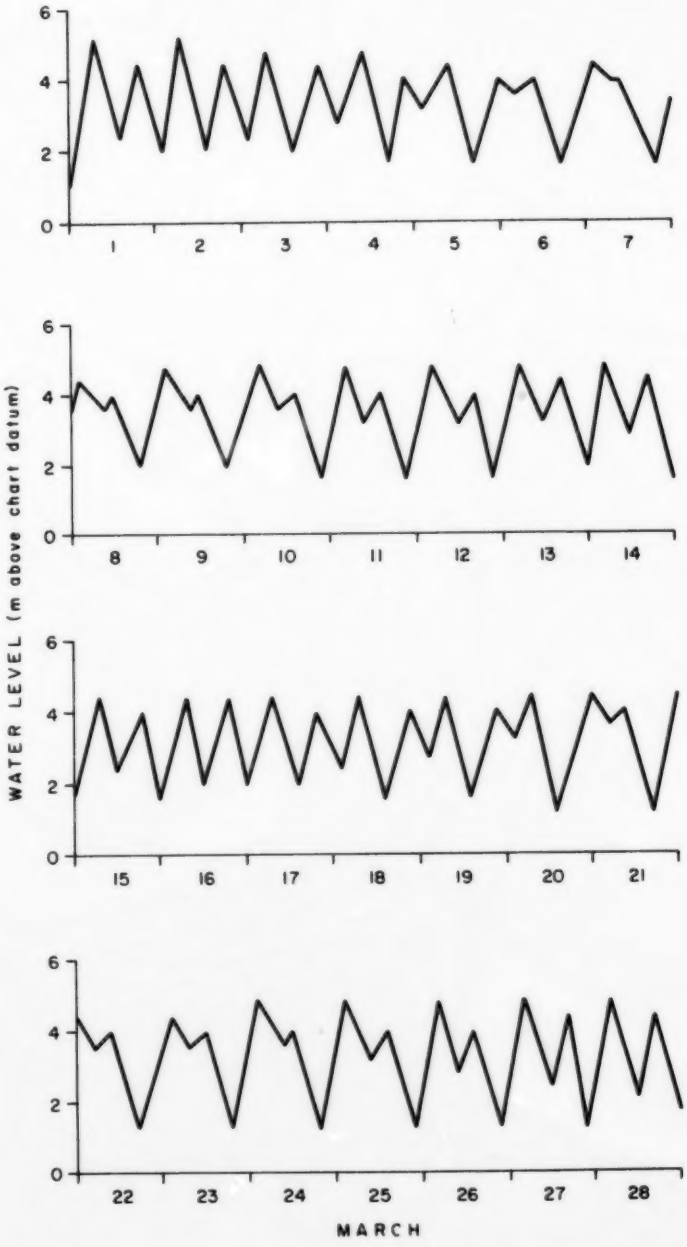

Fig. 12. Observed tide levels for herring egg incubation period in Lambert Channel in 1983.